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7.1 MAIN STEAM SUPPLY SYSTEM

Learning Objectives:

1. State the purposes of the main steam supply system.

2. Describe the major differences between the main steam supply systems of the AP1000 and currently operating Westinghouse plants.

7.1.1 Introduction

The purposes of the main steam supply system are to:

1. Transfer steam from the steam generators to the turbine-generator and auxiliary steam systems,
2. Provide overpressure protection for the steam generators, and
3. Provide a path for decay heat removal.

The function of the main steam supply system is to supply steam from the steam generators to the turbine elements over a range of flows and pressures covering the entire operating range from system warmup to maximum calculated turbine conditions.

The system provides steam to the moisture separator/reheaters and the gland seal system for the main turbine. The system dissipates heat generated by the nuclear steam supply system (NSSS) by means of steam dump valves to the condenser when the turbine-generator is unavailable, or to the atmosphere through power-operated atmospheric relief valves or spring-loaded main steam safety valves when neither the turbine-generator nor the condenser is available.

The following main steam supply system components of each steam line are classified as equipment class B and are safety related:

- The main steam line piping from the steam generator up to, and including, the main steam isolation valve,
- The main steam isolation valve bypass piping up to, and including, the main steam isolation bypass valve,
- The inlet piping from the main steam line up to, and including, the main steam safety valves,
- The inlet piping from the main steam line up to, and including, the power-operated relief valve block valve,
- The instrumentation piping up to, and including, the main steam line pressure instrument root valves,
- The vent line on the main steam line up to, and including, the first isolation valve, and the nitrogen connection on the main steam line up to, and including, the first isolation valve, and

- The main steam drain condensate pot located upstream of the main steam isolation valve, and the drain piping up to, and including, the first isolation valve.

The following main steam supply system components of each steam line are classified as equipment class C and are safety related:

- The main steam line piping from the main steam isolation valves outlet to the pipe restraint located on the wall between the auxiliary building and the turbine building,
- The main steam safety valve discharge piping and vent stacks,
- The piping from the outlet of the power operated relief block valve up to, and including,the power operated relief valve, and
- The condensate drain piping from the outlet of the class B isolation valve to the restraint on the wall between the auxiliary building and the turbine building.

The remainder of the main steam supply system is not safety related.

7.1.2 System Description

The function of the main steam supply system is to supply steam from the steam generators to the turbine elements over a range of flows and pressures covering the entire operating range from system warmup to maximum calculated turbine conditions.

The system also provides steam to the moisture separator/reheaters and the gland seal system for the main turbine. The system dissipates heat generated by the nuclear steam supply system (NSSS) by means of steam dump valves to the condenser when the turbine-generator is unavailable, or to the atmosphere through power-operated atmospheric relief valves or spring-loaded main steam safety valves when neither the turbine-generator nor the condenser is available.

7.1.3 Component Descriptions

The main steam supply system shown in Figure 7.1-1 includes the following major components:

- Main steam piping from the steam generator outlet steam nozzles to the main turbine stop valves,
- One main steam isolation valve and one main steam isolation valve bypass valve per main steam line,
- Main steam safety valves, and
- Power-operated atmospheric relief valves and associated upstream isolation valves.

7.1.3.1 Main Steam Piping

The main steam lines deliver steam flows from the secondary sides of the two steam generators. A portion of the combined main steam flow is directed to the reheaters and steam seals, with the turbine receiving the remaining steam flow. Table 7.1-1 lists the performance data for the main steam supply system. Each of the main steam lines from the steam generators is anchored at the auxiliary building wall and has sufficient flexibility to accommodate thermal expansion.

The two main steam lines are cross-connected into a common header just before it branches to supply each turbine stop valve. This arrangement equalizes flows and pressures to the inlets of the turbine stop valves. This also permits online testing of each turbine stop valve without exceeding the allowable limit on steam generator pressure differential. Each steam generator outlet nozzle contains an internal flow restrictor arrangement to limit flow in the event of a main steam line break.

Turbine bypass (steam dump) valves are provided between the main steam isolation valves and the turbine-generator stop valves.

Branch connections are provided from the main steam system for various functions. Upstream of the main steam isolation valves, there are connections for the power-operated atmospheric relief valves, main steam safety valves, low point drains, high point vents, and nitrogen blanketing. Branch piping downstream of the main steam line isolation valves includes connections for the second-stage reheater steam supplies, gland seal system, turbine bypass system, auxiliary steam system, and low point drains.

7.1.3.2 Main Steam Safety Valves

Main steam safety valves with sufficient rated capacity are provided to prevent the steam pressure from exceeding 110 percent of the main steam system design pressure:

- Following a turbine trip without a reactor trip and with main feedwater flow maintained, and
- Following a turbine trip with a delayed reactor trip and with the loss of main feedwater flow.

The total main steam safety valve rated capacity as indicated in Table 7.1-2 meets this requirement. At the same time, each individual safety valve is limited to the maximum allowable steam relief valve capacity as indicated in Table 7.1-2 for a system pressure equal to main steam design pressure plus 10 percent overpressure. This value sufficiently limits the potential uncontrolled blowdown flow and the ensuing reactor transient should a single safety valve inadvertently fail or stick in the open position.

Six safety valves are provided per main steam line for the plant. Table 7.1-2 lists the set pressures for the main steam safety valves. The main steam supply system safety valves are located in the safety-related portion of the main steam piping

upstream of the main steam isolation valves and outside the containment in the auxiliary building.

7.1.3.3 Power-Operated Atmospheric Relief Valves

A power-operated atmospheric relief valve is installed on the outlet piping from each steam generator to provide for controlled removal of reactor decay heat during a normal reactor cooldown when the main steam isolation valves are closed or the turbine bypass system is not available. The valves are sized to provide a flow as indicated in Table 7.1-1. The maximum capacity of the relief valve at design pressure is limited to reduce the magnitude of a reactor transient if one valve inadvertently opens and remains open.

Each power-operated relief valve is located outside the containment in the auxiliary building upstream of the main steam isolation valves, in the safety-related portion of the main steam line associated with each steam generator. This location permits valve operation following transient conditions, including those which could result in closure of the main steam isolation valves.

The operation of the power-operated relief valves is automatically controlled by steam line pressure during plant operations. The power-operated relief valves automatically modulate open and exhaust to atmosphere whenever the steam line pressure exceeds a predetermined setpoint. As steam line pressure decreases, the relief valves modulate closed, reseating at a pressure at least 10 psi below the opening pressure. The setpoint is selected between no-load steam pressure and the set pressure of the lowest set safety valves.

The steam generator power-operated atmospheric relief valves provide a non-safety-related means for plant cooldown by discharging steam to the atmosphere when the turbine bypass system is not available. Under such circumstances, the relief valves (in conjunction with the startup feedwater system) allow the plant to be cooled down at a controlled cooldown rate and depressurized from the pressure setpoint of the lowest set of safety valves down to the point where the normal residual heat removal system (RNS) can remove the reactor heat.

For their use during plant cooldown, the power-operated atmospheric relief valves are automatically controlled by steam line pressure, with remote manual adjustment of the pressure setpoint from the control room or the remote shutdown workstation. To effect a plant cooldown, the operator manually adjusts the pressure setpoint downward in a step-wise fashion. The maximum cooldown rate achievable is limited by the flow-passing capability of the relief valves, by the number of steam generators (and hence the number of relief valves) in service, by the available startup feedwater pumping capacity, and by the desire to either maintain or recover steam generator water levels during the cooldown.

The power-operated atmospheric relief valves also help to avoid actuation of the safety valves during certain transients and, following safety valve actuation, act to assist the safety valves to positively reseat by automatically reducing and regulating steam pressure to a value below the safety valve reseating pressure. The operation of each power-operated atmospheric relief valve is controlled in response to

measurements of steam line pressure provided by four separate pressure taps on the associated steam line.

The valve operator is an air-operated modulating type, providing throttling capability over a range of steam pressures. The atmospheric relief valves are controlled by non-safety-related control systems for the modulating steam relief function. The capability for remote-manual valve operation is provided in the main control room and at the remote shutdown workstation. A safety-related solenoid is provided to vent the air from the valve operator to terminate a steam line depressurization transient.

An isolation valve with remote controls is provided upstream of each power-operated relief valve. It provides isolation of a leaking or stuck-open valve. The upstream location allows for maintenance on the power-operated relief valve operator at power. The motor-operated isolation valve employs a safety-related operator and closes automatically on low steam line pressure to terminate steam line depressurization transients. The isolation valve is a containment isolation boundary and therefore is specified as safety-related, active, ASME Code, Section III, Safety Class 2.

7.1.3.4 Main Steam Isolation Valves

The function of main steam isolation is to limit steam blowdown to the inventory of one steam generator in the event of a steam line break to:

- Limit the effect upon the reactor core to within specified fuel design limits, and
- Limit containment pressure to a value less than design pressure.

Main steam isolation consists of one quick-acting gate valve in each main steam line and one associated globe main steam isolation bypass valve with associated actuators and instrumentation. These valves are located outside the containment, downstream of the steam generator safety valves and the atmospheric relief valve, in the auxiliary building. The isolation valves provide positive shutoff with minimum leakage during postulated line severance conditions either upstream or downstream of the valves.

The main steam isolation valves close fully upon receipt of a manual or automatic signal and remain fully closed. Upon receipt of the closing signal, each main steam isolation valve completes its closing cycle even with the loss of normally required utility services for its actuator and/or associated instrumentation. On a loss of actuating gas-hydraulic power, the valves fail to the closed position. Position indication for and remote-manual operation of the isolation valves are provided in the control room and remote shutdown workstation. Additionally, provisions are made for in-service inspection of the isolation valves.

Closure of the main steam isolation valves and main steam isolation bypass valves is initiated by the following:

- Low steam line pressure in either steam line,
- High containment pressure,

- High negative steam pressure rate in either steam line,
- Low T_{cold} in either reactor coolant loop, and
- Manual actuation.

There are four controls for manual main steam line isolation. Two of the controls provide system level actuation, that is, isolate both steam lines. Each of the other two controls, one per steam line, provides isolation of a single steam line. In addition, there are two controls for manual reset of the steam line isolation signal, one for each of the logic divisions associated with steam line controls. Each can be used to manually reset one division's steam line isolation signal.

Each main steam isolation valve is a bidirectional wedge-type gate valve with a valve body that is welded into the system pipe. The main steam isolation gate valve is provided with a hydraulic/pneumatic actuator. The valve actuator is supported by the yoke, which is attached to the top of the body. The valve actuator consists of a hydraulic cylinder with a stored energy system to provide emergency closure of the isolation valve. The energy to operate the valve is stored in the form of compressed nitrogen contained in one end of the actuator cylinder. The main steam isolation valve is maintained in a normally open position by high-pressure hydraulic fluid. For emergency closure, redundant solenoids are energized, resulting in the high-pressure hydraulic fluid being dumped to a fluid reservoir.

The main steam isolation bypass valves are used to permit warming of the main steam lines prior to startup when the main steam isolation valves are closed. The bypass valves are modulating, air-operated globe valves. For emergency closure, redundant 1E solenoids are provided. Each solenoid is energized from a separate safety-related division.

7.1.4 System Operation

7.1.4.1 Normal Operation

During normal power operation, the main steam supply system supplies steam to meet the demands of the main turbine system. The main steam supply system also supplies steam as required to the auxiliary steam system, and reheating steam to the moisture separator reheaters. The main steam supply system also provides steam to the turbine gland seal system.

The main steam supply system is capable of accepting a ±10-percent step change in load followed by a ±5-percent/min ramp change without discharging steam to the atmosphere through the main steam safety valves or to the main condenser through the turbine bypass system. For large step-change load reductions, steam is bypassed (up to 40 percent of full load flow) directly to the condenser via the turbine bypass system. The main steam supply system, in conjunction with the turbine bypass system, is capable of accepting a 100-percent net load rejection without reactor trip (in conjunction with a reactor rapid power reduction) and without lifting safety valves. If the turbine bypass system is not available, steam is vented to the atmosphere via the power-operated atmospheric relief valves and the main steam safety valves, as required.

7.1.4.2 Emergency Operation

In the event that the plant must be shut down with the steam lines isolated, the main steam isolation valves, their associated main steam isolation bypass valves, and other valves associated with the main steam lines can be closed. The power-operated atmospheric relief valves are then used to remove reactor decay heat and primary system sensible heat to cool down to conditions at which the normal residual heat removal system can perform the remaining cooldown function. If the power-operated atmospheric relief valve for an individual main steam line is unavailable because of the loss of its control or power supply, the respective safety valves will provide overpressure protection. The remaining power-operated atmospheric relief valve is sufficient to cool down the plant.

In the event that a design-basis accident occurs, resulting in a large steam line break, the main steam isolation valves and their associated main steam isolation bypass valves automatically close. These closures assure that no more than one steam generator supplies a postulated break. The passive residual heat removal system provides safety-related decay heat removal capability should steam relief and feedwater be unavailable.

Table 7.1-1

MAIN STEAM SUPPLY SYSTEM DESIGN DATA

Steam Flow (lb/hr)	**Maximum Calculated**
Per steam generator	7.49×10^6
Total	14.97×10^6
Design Conditions	
Design pressure (psia)	1200
Design temperature (°F)	600°F
Operating Conditions	
Full plant load pressure (psia)	836
Full plant load temperature (°F)	523.3
No load (hot standby) pressure (psia)	1106
No load (hot standby) temperature (°F)	557
Main Steam Piping: See Table 10.3.2-3.	
Steam Generator Flow Restrictor	
Number per steam generator outlet nozzle	7
Throat size (ft^2)	0.2
Total area (ft^2)	1.4
Power-Operated Relief Valve	
Number per main steam line	1
Normal set pressure	1138 psig
Design capacity	
Minimum:	70,000 lb/hr at 100 psia steam generator pressure
Maximum:	1,020,000 lb/hr at 1200 psia steam generator pressure
Code	ASME Code, Section III, Class 3, seismic Category I
Actuator	Air-operated modulating

Table 7.1-2

DESIGN DATA FOR MAIN STEAM SAFETY VALVES

Number per main steam line		6
Total number of valves required per steam line for full power operation		6
Relieving capacity per valve at 110% of design pressure		1,370,000 lb/hr
Relieving capacity per steam line at 110% of design pressure		8,240,000 lb/hr
Total relieving capacity, 2 lines at 110% of design pressure		16,480,000 lb/hr
Valve size		8 x 10 (Dual Discharge)
Design code		ASME Code, Section III, Class 2, seismic Category I
Valve Number	**Set Pressure (psig)**	**Relieving Capacity[(a)] (lb/hr)**
SGS PL V030A(B)	1185	≥ 1,320,000
SGS PL V031A(B)	1197	≥ 1,340,000
SGS PL V032A(B)	1209	≥ 1,350,000
SGS PL V033A(B)	1221	≥ 1,360,000
SGS PL V034A(B)	1232	≥ 1,370,000
SGS PL V035A(B)	1232	≥ 1,370,000
Total capacity, at 103% valve setpoint pressures, 2 lines		≥ 16,220,000

Note:

a. Based on system accumulation pressure of 3%, per Subsection NC-7512 of ASME Code, Section III, Division 1, 1989 Edition, Subsection NC, Class 2 components.